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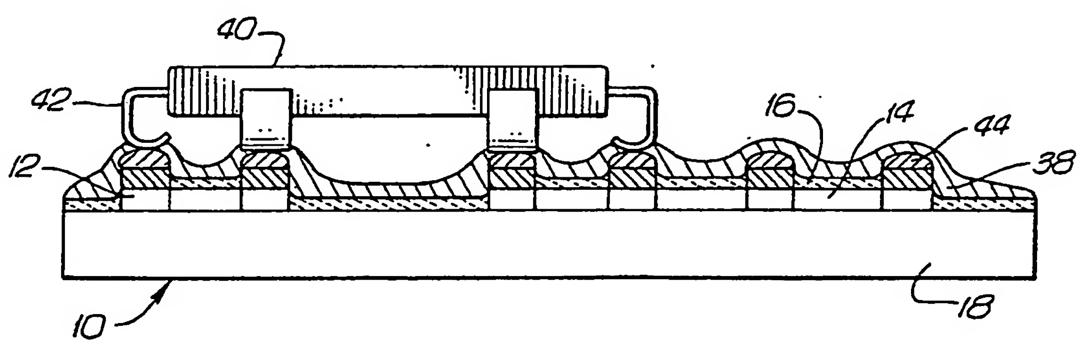

(57) Abstract

A method for soldering surface mountable electronic components (40) to a printed circuit board (10) is described. The method involves the use of a wave soldering machine (22) to coat the pads (12) of the printed circuit board (10) with solder (26). After the pads (12) are coated with solder (26), the entire surface of the board (10) is covered with flux paste (38). Then, surface mountable electronic components (40) are positioned on the board (10). The viscous flux (38) coating holds the leads of each electronic component (40) to the pads (12) until the board (10) is placed in a furnace. The heat from the furnace first melts the flux (38) which chemically cleans the surface of the solder coated pads (12). Further increases in temperature melt the solder coating (44) to solder the component leads (42) to the pads (12). When the board (10) is subsequently removed from the furnace, the solder cools and resolidifies to electrically and mechanically connect the leads (42) to the pads (12).

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SOLDER PASTE REPLACEMENT METHOD AND ARTICLE

BACKGROUND OF THE INVENTION

The present invention relates to a process for soldering surface-mountable electronic components to a printed circuit board.

Printed circuit boards are used in a wide variety of electronic devices. The boards serve to support the electronic circuit components of the devices while conductive material on the surface of the insulating board substrate supplies power to and interconnects the component leads. In conventional perforated printed circuit boards, each component lead is inserted into a hole which is drilled through the board substrate. The hole walls are frequently plated with the conductive material. Each hole is also surrounded by a ring of the conductive material. This ring is called a "pad". Filaments of the conductive material, called "traces", interconnect the pads in a predetermined manner so that, after the component leads are soldered to the pads and hole walls, the components form a functioning circuit.

Printed circuit board manufacturers frequently plate both the pads and the plated hole walls with a thin layer of a tin-lead mixture. The board is then heated in a furnace until the tin and lead melt together to form a solder coating over the pads and hole walls. When the leads of the electronic components are subsequently soldered to the board, this thin solder coating or "tinning" helps to produce a good electrical

and mechanical connection between the component leads and the pads.

To make the board as compact as possible, the pads and traces are usually small and placed close together. However, when the component leads are soldered to the pads, additional solder must be applied to the pads to create a good electrical and mechanical connection between the pads and the leads. Thus, since only small distances separate adjacent pads and traces, there is a danger that this additional molten solder might flow from one or more of the pads to adjacent pads or traces and thereby produce unwanted short circuits.

To prevent these unwanted short circuits, the entire surface of the board, except for the pads, is protected with a coating of solder-mask before the components are mounted on the board. Solder-mask is an electrically insulating material which is resistant to the high temperature of molten solder. A number of well known techniques exist for applying solder-mask to the board while leaving the pads bare. For example, if a light sensitive solder-mask is used, then photographic techniques may be utilized to cover the board surface with solder-mask while leaving the pads bare. Alternatively, if non-photosensitive solder-mask material is used, then the solder-mask can be applied to the board using silk screening procedures.

After the traces are protected from unintentional short circuiting with solder-mask, the board is positioned so that the surface of the board which supports the pads and traces faces down. Then, the electronic components are mounted to these conventional boards by positioning the components over the upper surface of the board and inserting the leads into the holes which run through the center of each pad. In an

automated assembly line, a mechanical device called a "pick and place machine" is frequently used to place the components on the board and insert their leads into the proper holes. After the electronic components are positioned by the pick and place machine, the board travels along the assembly line to a position where the components are soldered to the board with a wave soldering machine.

A wave soldering machine is a mechanism which has jets for spraying the exposed pads of the printed circuit board with a liquid flux and a soldering surface. The soldering surface is formed from a hollow horizontally disposed member (e.g. a cylinder) having holes along its upper surface. A pump disposed below the cylinder supplies molten solder to the holes. The molten solder oozes out of the holes and flows over the surface of the cylinder. This flow of molten solder is called a solder wave.

As the printed circuit board travels through the wave soldering machine, the bottom side of the board, which supports the pads and traces, is first sprayed with the liquid flux to remove any grease, dirt and oxidized solder which may have accumulated on the surface of the exposed pads. The flux does not affect the solder-mask. Then, the bottom of the board is brought into contact with the solder wave. Molten solder from the solder wave coats the pads and is drawn up into the holes in the printed circuit board by capillary action. In this way, the molten solder solders the component leads which are in the holes to the hole walls and to the pads. Once the printed circuit board moves past the wave soldering machine, the solder coating on the pads and in the holes resolidifies, thereby electrically and mechanically affixing the components to the board. Since the wave

soldering method requires only relatively inexpensive liquid flux and molten solder, it is an economical way to solder electronic components to conventional perforated printed circuit boards.

In contrast to conventional perforated printed circuit boards, state-of-the-art surface mount technology (hereinafter "SMT") eliminates the need for the holes through the board. Instead, SMT techniques solder component leads directly to pads at the surface of the board. With SMT, all or most of the component leads do not pass straight through holes in the board. Instead, the leads on surface mountable components are bent into a variety of shapes, including, for example, the shape of the letter "J". This type of lead is called a J-lead. Rather than being inserted into a hole in the board, the bottom curved portion of each J-lead simply rests on the surface of a pad. In subsequent processing steps, each J-lead is soldered to its supporting pad.

Since SMT boards do not have holes with which to receive component leads, many surface mountable electronic components previously could not be easily soldered to the top of SMT boards using the efficient and inexpensive wave soldering method. Instead, surface mount technology has relied on "solder paste" to provide the solder for soldering surface mountable components to surface mount boards. Solder paste is a mixture of finely divided particles of solder, flux and solvents. A silk screening process is used to apply the solder paste to SMT boards. As with conventional perforated boards, the pads are first tinned with a thin layer of solder. Then, the entire surface of the printed circuit board, except for the pads, is covered with solder-mask. A silk screen is subsequently placed directly on top of the solder-masked board. The silk screen has holes in

it which correspond to the locations of the pads on the board. Solder paste is then spread over the silk screen. If the silk screen is properly aligned with the board, only the pads should be coated with solder paste when the silk screen is removed.

The solder paste silk screening process, however, has numerous disadvantages. First, because the pads are so small and are separated by similarly small distances, the silk screening process requires extremely precise alignment of the silk screen and the printed circuit board to ensure that the solder paste is applied only to the pads. If the screen is misaligned, the pads will not receive a coating of solder paste and the tinning solder alone will not provide enough solder to form a good electrical connection between the pads and the leads. Second, solder paste is made by first finely dividing solder and then mixing the solder particles with flux paste and solvents. The solder paste manufacturing process requires precise control over the size of the solder particles and the relative amounts of solder and flux. The amount of solvents used must also be precisely controlled since the amount of solvents control the viscosity of the solder paste. Thus, solder paste is far more expensive than the simple liquid flux and molten solder used in the wave soldering machine. Third, when the solder paste is heated, bubbles of vaporized flux and solvent frequently become trapped in the molten solder between the pads and the component leads. These bubbles weaken the solder connections and also increase the electrical resistance of the connections. Furthermore, the pressure of the vaporized flux and solvents which do escape from between the leads and the pads cause the solder to flow laterally. This phenomenon can short out adjacent pads. The pressure of

the escaping gases can also produce flares of solder which solidify into solder balls. These solder balls can lodge between adjacent leads and thereby cause unwanted short circuits.

The present invention avoids many of the drawbacks associated with the previously known solder paste techniques and instead substitutes a method whereby a wave soldering machine can be used to solder surface mountable components to an SMT board cheaply, effectively and efficiently.

SUMMARY OF THE INVENTION

The purpose of the previously described solder paste method is to provide solder at the site where the electronic component leads contact the pads so that the solder can electrically and mechanically connect the leads to the pads. The present invention accomplishes this same objective, but without using solder paste and in a far more efficient and economical fashion.

According to the present invention, the electronic device manufacturer first obtains an SMT printed circuit board having the proper arrangement of pads, traces interconnecting the pads, and a coating of solder-mask. In the present invention, as in conventional SMT solder-masking processes, virtually the entire surface of the board is coated with solder-mask material, including the exposed portions of the insulating board substrate as well as the traces. Only the pads remain bare. SMT printed circuit boards are generally obtained from printed circuit board manufacturers with tinned pads. The present process will work if the pads are tinned. However, it is not required in the present inventive process that the pads of the printed circuit boards be tinned. The process will work equally well even if the pads are not tinned.

To perform the present inventive process, the SMT circuit board is positioned so that the surface having the pads which are to be supplied with solder faces down. The board is then run through the wave soldering machine. As previously explained, wave soldering machines typically have a first station which sprays the board with a liquid flux to remove any grease, dirt or oxides which may have accumulated on the exposed surface of the pads. Then, the board is passed over the solder wave so that the pads contact the molten solder. In this way, each of the pads obtains a solder coating. After

the board passes out of the wave soldering machine, the molten solder on the pads cools and solidifies.

It is important to note that the molten solder will not stick to the solder-mask. Therefore, when the printed circuit board emerges from the wave soldering machine, only the pads are coated with solder. Thus, without using the silk screening procedures which are a necessary part of the solder paste process, the present inventive process provides a self-aligned solder coating over only the pads.

When the board emerges from the wave soldering machine it is once again flipped over so that the solder coated pads are positioned on the upper side of the board. The board is then coated with soldering flux paste. This flux coating can be provided in any number of ways. The exact method of coating the board is not usually material to the invention, provided that each of the solder coated pads receives a flux coating. It is envisioned that the board could be easily coated with flux by simply wiping a flux covered pad over the surface of the board, spraying flux onto the board or brushing the flux on. It is important that each of the pads receive a coating of flux. In addition, however, the remainder of the board surface may also be coated with flux without affecting the efficacy of the process. In fact, it is a particular advantage of the present process that the flux does not need to be dispersed only over the printed circuit board pads but, instead, the entire surface of the board can be coated with flux by any of the easy, cheap and simple processes described above.

The surface mountable electronic components are then positioned on the board in the correct locations so that their leads rest on the proper pads. The

components can be positioned by hand or by automated pick-and-place machines. Because the flux is viscous, it will hold the leads in position so that the components will not be knocked off of their pads by any impacts or vibrations which may occur as the board travels along the assembly line.

The entire board is then exposed to a heat source, for example, the board may be placed in a furnace. The heat of the furnace will first liquify the flux which is spread over the surface of the board so that the hot liquid flux chemically cleans the surface of the solder coated pads. Then, as the board heats up further, the solder coating on the pads will also melt and solder the leads to the pads. When the board is later removed from the furnace, the molten solder will resolidify, thereby electrically and mechanically connecting the components to the pads. Any residual flux which remains on the board surface can be subsequently removed with conventional solvents or aqueous cleaners.

In the present invention, the flux covers the solid solder coating on the pads rather than being mixed with solder particles as it is in the solder paste method. Since the present invention never mixes the solder and the flux together, it avoids the formation of bubbles of vaporized flux and vaporized flux solvents which frequently form in the solder connections resulting from the solder paste method. As previously mentioned, these bubbles degrade the electrical and mechanical quality of the solder connections. Additionally, the pressure of the escaping vaporized flux and solvents causes solder balls that can short out the components which are soldered to be board.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 is a simplified perspective view of a typical printed circuit board designed for surface mountable electronic components. Solder-mask, indicated by the hatch lines, protects the entire surface of the board, except for the pads which remain exposed.

FIGURE 2 is a cross-sectional view taken along the line 2-2 of the board of Fig. 1. The board is shown in an inverted position being moved from left to right across the top of the cylinder of the wave soldering machine.

FIGURE 3 illustrates the board after the pads have been coated with solder by the wave soldering machine and the entire board has been subsequently coated with flux paste.

FIGURE 4 illustrates the board of Fig. 3 after a surface mountable J-lead integrated circuit is positioned on the pads but before the board is heated in a furnace to melt the flux and solder.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Figs. 1-4 sequentially illustrate the major processing steps of the present invention. Figure 1 illustrates, in simplified form, a printed circuit board 10 designed for use with surface mountable components. The board 10 has pads 12 and traces 14 interconnecting the pads 12 in a desired fashion so as to form a functioning circuit when the SMT components are soldered to the pads 12. In addition, as indicated by the hatch lines, solder-mask 16 covers the traces and the exposed areas of the insulating substrate 18. The pads 12 are not covered with solder-mask 16 so that they can be soldered to the leads of surface mountable electronic components during later processing steps.

To cover the board 10 with solder-mask 16 yet leave the pads 12 uncovered, unpolymerized photosensitive solder-mask 16 material is spread over the entire surface of the board 10 so that a thin film of solder-mask covers the pads 12, traces 14 and the exposed areas of insulating board substrate 18. A commonly used photosensitive solder-mask 16 is sold under the trademark VACREL. After the board 10 is coated with the film of solder-mask 16, a partially opaque mask (not shown) is laid over the board 10 so that the opaque portions of the mask shade only the pads 12. The remainder of the board 10 is exposed to ultraviolet light through the transparent parts of the mask to polymerize the film of solder-mask 16. The solder-mask 16 over the pads 12, however, remains unpolymerized since the pads 12 are shaded from the ultraviolet light by the opaque portions of the mask. The unpolymerized solder-mask is then removed from the pads 12 by well known solvents which dissolve unpolymerized solder-mask but which will not dissolve

the polymerized solder-mask material. The resulting SMT printed circuit board 10 has a coating of solder-mask 16 protecting almost the entire surface of the board 10 but which leaves the pads 12 exposed.

Photosensitive solder-mask is generally preferred over non-photosensitive solder-mask because of the superior resolution obtainable with photographic masking processes. However, if the superior resolution of photosensitive solder-mask is not required, then non-photosensitive solder-mask may be used. If non-photosensitive solder mask is used, the board surface can be covered with a thin film of the non-photosensitive solder-mask while leaving the pads 12 bare by applying the non-photosensitive solder-mask to the board 10 in a silk screening process.

Each of the exposed pads 12 in the illustrated embodiment is tinned with a thin coating of solder 20 (see Fig. 2). However, the tinning coat of solder 20 is not absolutely necessary to the invention and can be omitted. Furthermore, the particular arrangement of pads 12 and traces 14 in this figure is for illustrative purposes only. Any actual printed circuit board would have pads 12 and traces 14 interconnecting the pads 12 in a pattern which would be designed to carry out the intended functions of the particular circuit.

Fig. 2 is a cross-sectional view of the board 10 of Fig. 1 taken along the line 2-2. In this figure, the board 10 is shown inverted so that the side of the board 10 having the pads 12 and traces 14 faces down. Only those parts of the wave soldering machine 22 necessary for an understanding of the present invention are shown. Any actual wave soldering machine will also have a number of mechanisms for accomplishing its intended purpose, such as heaters to melt the solder, a pump and

a mechanism for transporting the boards through the solder wave 26. However, for the sake of a clear illustration, in addition to the printed circuit board 10, Fig. 2 only depicts the jets of flux 30, the molten solder wave 26 and the solder-coated cylindrical member 28 which is used to help shape the wave 26. Moreover, instead of spraying a jet of flux 30 through a nozzle 24 at the board 10, some types of wave soldering machines 22 bubble foam through a porous material and then apply the flux foam to the board surface. With this type of wave soldering machine, the foaming device (not shown) would be located where the flux nozzle 24 is positioned in Fig. 2.

As the board 10 is conveyed through the wave soldering machine 22 by the transporting mechanism (not shown), the jets 24 spray the lower surface of the board 10 with liquid flux 30. The flux 30 cleans the exposed surface of the pads 12 by chemically removing any grease, dirt or oxides which may have accumulated on the solder coated pad surfaces 32.

After the flux 30 cleans the pads 12, the board 10 continues to be transported to the right of Fig. 2 so that the pads 12 contact the solder wave 26. The surface of the cylinder 28 is supplied with molten solder 26 by a pump (not shown) which pumps the molten solder 26 through holes 34 in the cylinder surface 36. The solder 26 then flows out of the holes 34 and down the curved surface of the cylinder 28. As the board 10 passes over the cylinder 28, the pads 12 successively pick up a relatively thick coating of solder 44 (Fig. 3). Solder will not stick to the solder-mask 16. Thus, after the board 10 completely passes over the cylinder 28, only the pads 12 are coated with solder 44.

Fig. 3 illustrates the board 10 again positioned upright so that the solder coated pads 12 are on the

upper surface of the board 10. In addition, Fig. 3 also shows a flux paste 38 coating the entire surface of the board 10. The board 10 may be coated with flux paste 38 by spraying the flux 38 onto the board, or wiping it on or brushing it on. The exact method of applying the flux 38 is immaterial, provided that the pads 12 are coated with the flux 38.

In the next step of the process of the present embodiment, surface mountable electronic components 40 are placed on the flux coated pads 12. Only one surface mountable integrated circuit 40 is illustrated in Fig. 4. However, actually, the number and placement of integrated circuits would depend on the intended function of the board 10. The viscous flux 38 will hold the integrated circuit 40, and any other surface mountable components, to the pads 12 as the board 10 is transported along the assembly line to the furnace (not shown).

Once the board 10 of Fig. 4 reaches the furnace, it is heated to first melt the flux 38. The melted flux chemically cleans contaminants such as grease, dirt or oxides off the solder coated pads 12. This cleaning improves the quality of the solder connections between the pads 12 and the component leads 42. Then, as the temperature continues to rise, the solder coating 44 on the pads 12 melts and the leads 42 are soldered to the pads 12 by the molten solder. The solder tinning 20 and the solder coating 44 from the wave soldering machine 22 are illustrated in the figures as two distinct layers. However, in reality these two layers would, of course, be melted together.

When the board 10 is subsequently removed from the furnace, the solder resolidifies to electrically and mechanically attach the component 40 to the board 10. The residual flux left on the board 10 when it leaves

the furnace can be removed by any number of well known cleaning techniques, for example, by cleaning the board surface with any number of well known solvents such as toluene or an aqueous cleaning agent.

One embodiment of the present invention has been described. Nevertheless, it is undertsood that various modifications may be made without departing from the spirit and scope of the invention. For example, the pads on both sides of a two-sided SMT board could be coated with solder by simply repeating the step illustrated in Fig. 2 with the board inverted so that the pads on the opposite side of the board receive a solder coating. Thus, the invention is not limited to the embodiment described herein but may be modified in various ways apparent to those skilled in the art.

I CLAIM:

1. A method for soldering the leads of electronic components to the pads of a printed circuit board, comprising the steps of:

(i) touching the surface of the pads of the printed circuit board to the surface of a supply of molten solder;

(ii) separating the pads from the molten solder supply so that only a small quantity of solder remains on the surface of the pads, said solder on the pad surfaces solidifying after separation from said molten solder supply; and

(iii) after step (ii), applying a coating of flux over the surface of said board.

2. The method of claim 1, further comprising the step of cleaning the surface of said pads prior to step (i).

3. The method of claim 1, further comprising the step of tinning the surface of said pads with a thin layer of solder prior to step (i).

4. The method of claim 3, further comprising the step of cleaning the tinned surface of the pads prior to step (i).

5. The method of claim 1, wherein said flux is applied by spraying the flux onto the surface of said board.

6. The method of claim 1, wherein said flux is applied by brushing the flux onto the surface of said board.

7. The method of claim 1, wherein said flux is applied by spreading the flux onto the surface of said board.

8. The method of claim 1, wherein said flux is applied by foaming the flux onto the surface of the board.

9. The method of claim 1, further comprising the steps of:

after step (iii), placing the leads of said electronic components on the flux coated pads;

melting the flux so that the flux chemically cleans the surface of the leads and the solder; and

then melting and later resolidifying the solder on the pads to electrically and mechanically connect the leads to the pads.

10. The method of claim 9, further comprising the step of removing the flux from the surface of the printed circuit board after conducting the steps of claim 7.

11. The method of claim 10, wherein the flux is removed with a liquid solvent.

12. The method of claim 11, wherein the flux is removed by spraying the surface of said printed circuit board with the liquid solvent.

13. The method of claim 11, wherein the flux is removed with an aqueous cleaning solution.

14. The method of claim 12, wherein said molten solder supply comprises:

a curved member; and

means for continuously coating the curved surface of said member with an aqueous cleaning solution.

15. The method of claim 1, wherein said molten solder supply comprises:

a curved member; and

means for continuously coating the curved surface of said member with molten solder.

16. An electronic circuit board, comprising:

an insulating substrate;

a plurality of spaced electrically conductive pads on the surface of said substrate;

electrically conductive traces on the surface of said substrate interconnecting said pads;

solidified solder coating the surface of said pads;

solder-mask covering the traces;

a coating consisting essentially of flux covering one entire side of said electronic circuit board; and

surface mountable electronic components having leads resting on said solder coated pads, wherein said flux is viscous and the distal ends of said leads are immersed in said flux and held by the viscosity of said flux to said pads.

Fig. 1

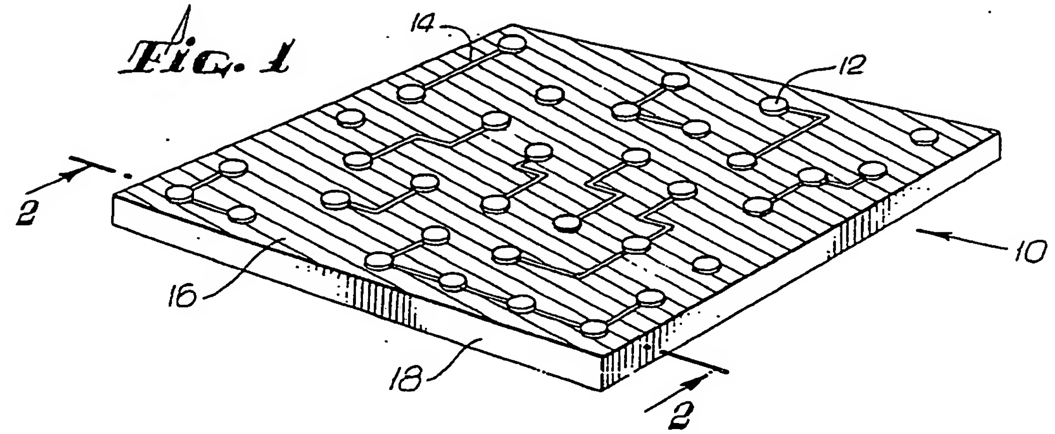


Fig. 2

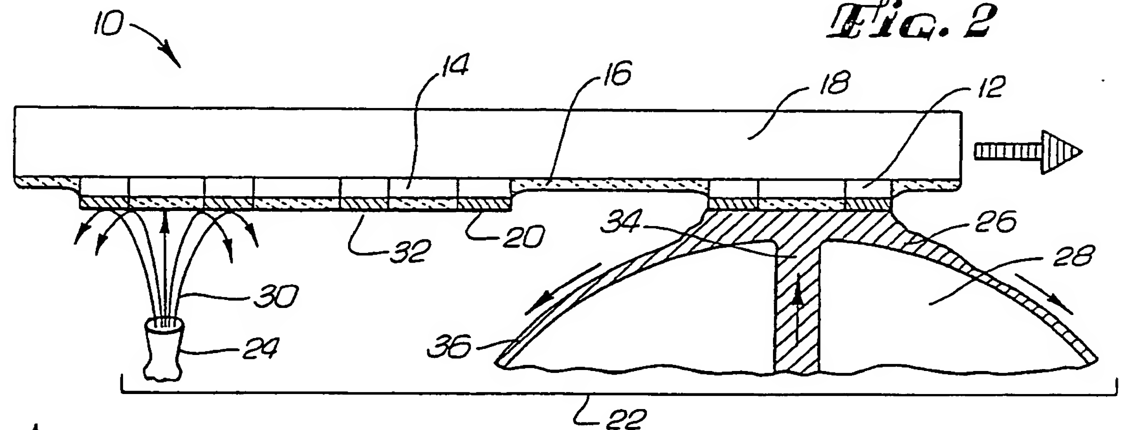


Fig. 3

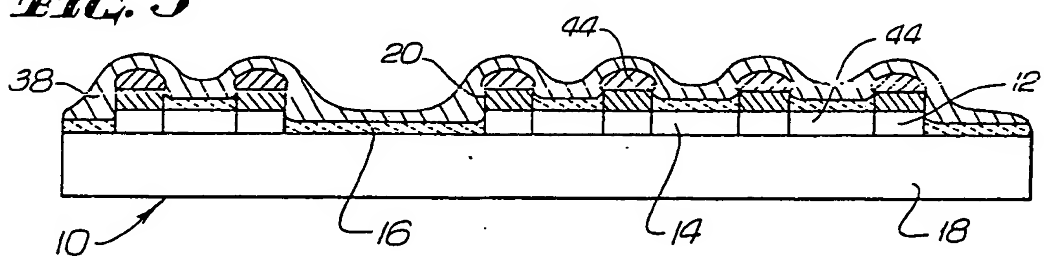
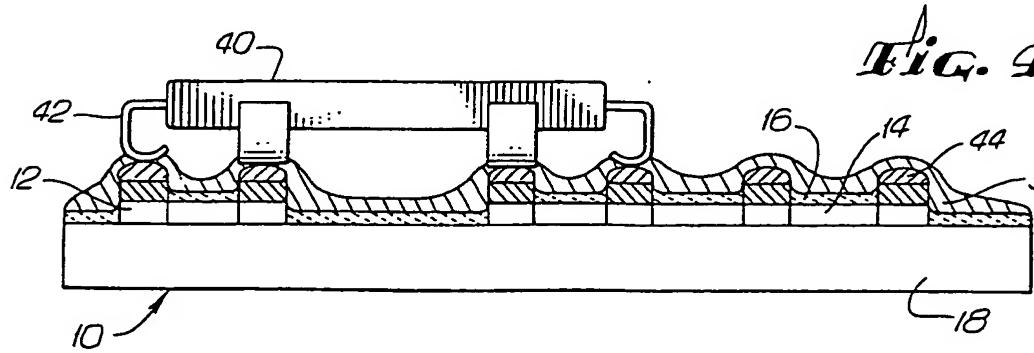


Fig. 4



INTERNATIONAL SEARCH REPORT

International Application No PCT/US 88/00619

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: H 05 K 3/34, B 23 K 1/08

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	H 05 K 3/00, B 23 K 1/00, B 23 K 3/00

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
X	US, A, 3717742 (STANLEY A. FOTTLER) 20 February 1973, see column 1, lines 48-64; column 3, lines 20-58; claims 2,6 --	1,9,15,16
A	FR, A, 2473834 (THOMSON-CSF) 17 July 1981, see page 2, lines 20-32; page 3, line 12 - page 4, line 15; page 1, lines 26-33; claims 1,2; page 6, line 21 - page 7, line 6; figure 3; claims 8,11 --	1,9,16
A	FR, A, 2498504 (WESTERN ELECTRIC CO.) 30 July 1982, see pages 4-6 --	10,11,12
A	EP, A, 0147000 (HOLLIS AUTOMATION INC.) 3 July 1985, see page 7, line 11 - page 8, line 6; page 8, lines 23-31 --	5,6,7,8
A	CA, A, 1219082 (VAN DEN BREKEL) 10 March 1987	

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* Special categories of cited documents: [10]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1st June 1988	12.07.88
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. US 8800619 SA 21422

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
The members are as contained in the European Patent Office EDP file on 23/06/88
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Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A- 3717742	20-02-73	None		
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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82